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THE SCIENTIFIC MONTHLY

DECEMBER, 1915

THE INSIDE HISTORY OF A GREAT MEDICAL DISCOVERY

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THE construction of the Panama Canal was made possible because it was shown that yellow fever, like malaria, could be spread only by the bites of infected mosquitoes.

The same discovery, which has been repeatedly referred to as the greatest medical achievement of the twentieth century, was the means of stamping out the dreaded scourge in Cuba, as well as in New Orleans, Rio de Janeiro, Vera Cruz, Colon, Panama and other cities in America.

This article is intended to narrate the motives that led up to the investigation and also the manner in which the work was planned, executed and terminated. No names are withheld and the date of every important event is given, so that an interested reader may be enabled to follow closely upon the order of things as they occurred and thus form a correct idea of the importance of the undertaking, the risk entailed in its accomplishment and how evenly divided was the work among those who, in the faithful performance of their military duties, contributed so much for the benefit of mankind; the magnitude of their achievement is of such proportions, that it loses nothing of its greatness when we tear away the halo of apparent heroism that well-meaning but ignorant historians have thrown about some of the investigators.

The whole series of events, tragic, pathetic, comical and otherwise, took place upon a stage made particularly fit by nature and the surrounding circumstances.

Columbia Barracks, a military reservation, garrisoned by some fourteen hundred troops, distant about eight miles from the city of Havana, the latter, suffering at the time from an epidemic of yellow fever, which the application of all sanitary measures had failed to check or ameliorate and finally, our experimental camp (Camp Lazear), a few army tents, securely hidden from the road leading to Marianao, and safeguarded against intercourse with the outside world; the whole setting portentously silent and gloriously bright in the glow of tropical sunlight and the green of luxuriant vegetation.

Two members of a detachment of four medical officers of the United States Army, on the morning of August 31, 1900, were busily examining under microscopes several glass slides containing blood from a fellow officer who, since the day before, had shown symptoms of yellow fever; these men were Drs. Jesse W. Lazear and myself; our sick colleague was Dr. James Carroll, who presumably had been infected by one of our "experiment mosquitoes."

It is very difficult to describe the feelings which assailed us at that moment; a sense of exultation at our apparent success no doubt animated us; regret, because the results had evidently brought a dangerous illness upon our coworker and with it all associated a thrill of uncertainty for the reason of the yet insufficient testimony tending to prove the far-reaching truth which we then hardly dared to realize.

As the idea that Carroll's fever must have been caused by the mosquito that was applied to him four days before became fixed upon our minds, we decided to test it upon the first non-immune person who should offer himself to be bitten; this was of common occurrence and taken much as a joke among the soldiers about the military hospital. Barely fifteen minutes may have elapsed since we had come to this decision when, as Lazear stood at the door of the laboratory trying to "coax" a mosquito to pass from one test-tube into another, a soldier came walking by towards the hospital buildings; he saluted, as it is customary in the army upon meeting an officer, but, as Lazear had both hands engaged, he answered with a rather pleasant "Good morning." The man stopped upon coming abreast, curious no doubt to see the performance with the tubes, and after gazing for a minute or two at the insects he said: "You still fooling with mosquitoes, Doctor?" "Yes," returned Lazear, "will you take a bite?" "Sure I ain't scared of 'em," responded the man. When I heard this, I left the microscope and stepped to the door, where the short conversation had taken place; Lazear looked at me as though in consultation; I nodded assent, then turned to the soldier and asked him to come inside and bare his forearm. Upon a slip of paper I wrote his name while several mosquitoes took their fill; William H. Dean, American by birth, belonging to Troop B, Seventh Cavalry; he said that he had never been in the tropics before and had not left the military reservation for nearly two months. The conditions for a test case were quite ideal.

I must say we were in great trepidation at the time; and well might we have been, for Dean's was the first indubitable case of yellow fever about to be produced experimentally by the bite of purposely infected mosquitoes. Five days afterwards, when he came down with yellow fever and the diagnosis of his case was corroborated by Dr. Roger P. Ames, U. S. Army, then on duty at the hospital, we sent a cablegram to Major Walter Reed, chairman of the board, who a month before had

been called to Washington upon another duty, apprising him of the fact that the theory of the transmission of yellow fever by mosquitoes, which at first was doubted so much and the transcendental importance of which we could then barely appreciate, had indeed been confirmed.

STATE OF THINGS BEFORE THE DISCOVERY OF MOSQUITO TRANSMISSION

Other infectious diseases, tuberculosis, for instance, may cause a greater death-rate and bring about more misery and distress, even to-day, than yellow fever has produced at any one time; but no disease, except possibly cholera or the plague, is so tragic in its development, so appalling in its action, so devastating in its results, nor does any other make greater havoc than yellow fever when it invades non-immune or susceptible communities.

For two centuries, at least, the disease has been known to exist endemically, that is, more or less continuously, in most of the Mexican Gulf ports, extending its ravages along the West India Islands and the cities of the Central and the South American coast.

In the United States it has made its appearance in epidemic form as far north as Portsmouth, N. H. At Philadelphia in 1793, more than ten per cent. of the entire population died of yellow fever. Other cities, like Charleston, S. C., suffered more than twenty epidemics in as many summers, during the eighteenth century. In the city of New Orleans, the epidemic which developed in the summer of 1853 caused more than 7,000 deaths. Later, in 1878, yellow fever invaded 132 towns in the United States, producing a loss of 15,932 lives out of a total number of cases which reached to more than 74,000: New Orleans alone suffered a mortality of 4,600 at that time. Recently (1905), this city withstood what is to be hoped shall prove its last invasion, which, thanks to the modern methods employed in its suppression, based upon the new mosquito doctrine, only destroyed about 3,000 lives.

It is by contemplating this awful record, and much more there is which for the sake of brevity I leave unstated, that one realizes the boon to mankind which the successful researches of the Army Board have proved. The work of prevention, the only one that may be considered effective when dealing with the epidemic diseases, was entirely misguided with regard to yellow fever until 1901: the sick were surrounded by precautions which were believed most useful in other infectious diseases, the attendants were often looked upon as pestilential, and so treated, in spite of the fact that evidence from the early history of the disease clearly pointed to the apparent harmlessness even of the patients themselves. All this notwithstanding, cases continued to develop, in the face of shotgun quarantine even, until the last non-immune inhabitant of the locality had been either cured or buried.

The mystery which accompanied the usual course of an epidemic. the

poison creeping from house to house, along one side of a street, seldom, crossing the road, spreading sometimes around the whole block of houses before appearing in another neighborhood, unless distinctly carried there by a visitor to the infected zone who himself became stricken, all this series of peculiar circumstances was a never-ending source of discussion and investigation.

In the year 1900, Surgeon H. R. Carter, of the then Marine Hospital Service, published a very interesting paper calling attention to the interval of time which regularly occurred between the first case of yellow fever in a given community and those that subsequently followed; this was never less than two weeks, a period of incubation extending beyond that usually accorded to other acute infectious diseases. The accuracy of these observations has later been confirmed by the mosquito experiments hereinafter outlined.

FACTORS WHICH LED TO THE APPOINTMENT OF THE BOARD

One may well believe that such a scourge as yellow fever could not have been long neglected by medical investigators, and so we find that from the earliest days, when the germ-theory of disease took its proper place in modern science, a search for the causative agent of this infection was more or less actively instituted.

Men of the highest attainments in bacteriology engaged in numerous attempts to isolate the yellow fever microbe: unfortunately not a few charlatans took advantage of the dread and terror which the disease inspires, to proclaim their discoveries and their specific *cures*; one of these obtained wealth and honor in one of the South American republics for presumably having discovered the "germ" and prepared a so-called vaccination which was expected to eradicate the disease from that country, but for many years after the foreign population continued to suffer as before and the intensity and the spread of yellow fever remained unabated, although thousands of "preventive inoculations" were made every month.

Geo. M. Sternberg in 1880, then an army surgeon, was directly instrumental in exposing the swindle that was being perpetrated, putting an end, after the most painstaking investigation, to all the claims to discovery of the "germ" of yellow fever that had been made by several medical men in Spanish America. The experience which he obtained during a scientific excursion through Mexico, Cuba and South America gave him a wonderful insight as to the difficulties one has to contend with in such work and made him realize the importance of special laboratory training for such undertaking. It is interesting to note that, as surgeon general of the U. S. Army, twenty years after, General Sternberg chose and appointed the men who constituted the yellow fever board. in Cuba.

The year before the Spanish-American war, an Italian savant, who had obtained a well-deserved reputation as bacteriologist while working in the Institute Pasteur of Paris, came out with the announcement from Montevideo, Uruguay, that he had actually discovered the much-sought-for cause of yellow fever; his descriptions of the methods employed, though not materially different from those followed by Sternberg many years before, bore the imprint of truth and his experimental inoculations had apparently been successful. Sanarelli—that is his name—for about two years was the “hero of the hour,” yet his claims have been proved absolutely false.

The question of the identity of his “germ” was first taken up by the writer under instructions from General Sternberg: during the Santiago campaign I had opportunity to autopsy a considerable number of yellow-fever cases and, following closely upon Sanarelli’s directions, only three times out of ten could his bacillus be demonstrated; at almost the same time, Drs. Reed and Carroll, in Washington, were carrying out experiments which showed that Sanarelli’s bacillus belonged to the hog-cholera group of bacteria and thus when found in yellow fever cadavers could play there only a secondary rôle as far as the infection is concerned.

Unfortunately, two investigators belonging to the U. S. Marine Hospital Service, Drs. Wasdin and Geddings, were, according to their claims, corroborating Sanarelli’s findings: there was nothing to do but that the investigation should continue, and so I was sent by General Sternberg to Havana in December, 1898, with instructions and power to do all that might be necessary to clear up the matter. Wasdin and Geddings had preceded me; the work carried us through the summer of 1899; we frequently investigated the same cases; I often autopsied bodies from which we took the same specimens and made the same cultures, in generally the same kind of media, and finally we rendered our reports to our respective departments, Wasdin and Geddings affirming that Sanarelli’s bacillus was present in almost all the cases, while I denied that it had such specific character and showed its occurrence in cases not yellow fever. A virulent epidemic which raged in the city of Santiago and vicinity during 1899 afforded me abundant material for research.

In the meantime the city of Havana was being rendered sanitary in a way which experience had taught would have overcome any bacterial infection, and, in fact, the diseases of filth, such as dysentery, tuberculosis, children’s complaints and others, decreased in a surprising manner, while yellow fever seemed to have been little affected if at all.

Evidently, a more thorough overhauling of the matter was necessary to arrive at the truth, and while the question of Sanarelli and his claims was practically put aside, Surgeon-General Sternberg, recognizing the importance of the work before us and that its proportions were such as to render the outcome more satisfactory by the cooperation of several

investigators in the same direction, wisely decided to create a board for the purpose and so caused the following to be issued:

Special Orders }
No. 122

HEADQUARTERS OF THE ARMY,
ADJUTANT GENERAL'S OFFICE,
WASHINGTON, May 24, 1900

Extract

34. By direction of the Secretary of War, a board of medical officers is appointed to meet at Camp Columbia, Quemados, Cuba, for the purpose of pursuing scientific investigations with reference to the infectious diseases prevalent on the Island of Cuba. Detail for the board:

Major Walter Reed, surgeon, U. S. Army;
Acting Assistant Surgeon James Carroll, U. S. Army;
Acting Assistant Surgeon Aristides Agramonte, U. S. Army;
Acting Assistant Surgeon Jesse W. Lazear, U. S. Army.

The board will act under general instructions to be communicated to Major Reed by the Surgeon General of the Army.

By command of MAJOR GENERAL MILES,
H. C. CORBIN,
Adjutant General

It may be of interest to the reader to learn who these men were and the reasons why they were probably selected for the work.

Major Reed, the first member in the order of appointment, was the ranking officer and therefore the chairman of the board. He was a regular army officer, at the time curator of the Army Medical Museum in Washington and a bacteriologist of some repute. He deservedly enjoyed the full confidence of the surgeon general, besides his personal friendship and regard. Reed was a man of charming personality, honest and above board. Every one who knew him loved him and confided in him. A polished gentleman and a scientist of the highest order, he was peculiarly fitted for the work before him.

Dr. James Carroll, the second member of the board, was a self-made man, having risen from the ranks through his own efforts: while a member of the Army Hospital Corps he studied medicine and subsequently took several courses at Johns Hopkins University in the laboratory branches. At the time of his appointment to the board he had been for several years an able assistant to Major Reed. Personally, Carroll was industrious and of a retiring disposition.

Dr. Jesse W. Lazear was the fourth member of the board. He had graduated from the College of Physicians and Surgeons (Columbia University) in the same class as the writer, in 1892, and had afterwards studied abroad and at Johns Hopkins. Lazear had received special training in the investigation of mosquitoes with reference to malaria and other diseases. Stationed at Columbia Barracks, he had been in

Cuba several months before the board was convened, in charge of the hospital laboratory at the camp. A thorough university man, he was the type of the old southern gentleman, kind, affectionate, dignified, with a high sense of honor, a staunch friend and a faithful soldier.

The writer was the third member of the Army Board. Born in Cuba during the ten years' war, while still a child, my father having been killed in battle against the Spanish, I was taken to the United States and educated in the public schools and in the College of the City of New York, graduating from the College of Physicians and Surgeons in 1892. At the breaking out of the war I was assistant bacteriologist in the New York Health Department. The subject of yellow fever research was my chief object from the outset, and, at the time the board was appointed, I was in charge of the laboratory of the Division of Cuba, in Havana.

It may be readily seen from the brief sketch regarding the several members that the components of the yellow-fever board really constituted a perfectly consistent body, for the reason, mainly, that they were all men trained in the special field wherein their labors were to be so fruitful and that before their appointment to the board they had been more or less associated in scientific work.

FIRST PART OF THE WORK OF THE BOARD

My first knowledge of the existence of the board was had through the following letter from my friend Major Reed:

WAR DEPARTMENT,
SURGEON GENERAL'S OFFICE,
WASHINGTON, May 25, 1900

DR. A. AGRAMONTE,
Act'g Asst. Surgeon U. S. A.,
Military Hospital No. 1,
Havana, Cuba.

My dear Doctor: An order issued yesterday from the War Department calls for a board of medical officers for the investigation of acute infectious diseases occurring on the Island of Cuba. The board consists of Carroll, yourself, Lazear and the writer. It will be our duty, under verbal instructions from the Surgeon General, to continue the investigation of the causation of yellow fever. The Surgeon General expects us to make use of your laboratory at Military Hospital No. 1 and Lazear's laboratory at Camp Columbia.

According to the present plan, Carroll and I will be quartered at Camp Columbia. We propose to bring with us our microscopes and such other apparatus as may be necessary for the bacteriological and pathological work. If, therefore, you will promptly send me a list of the apparatus on hand in your laboratory, it will serve as a very great help in enabling us to decide as to what we should include in our equipment. Any suggestions that you may have to make will be much appreciated.

Carroll and I expect to leave New York, on transport, between the 15th and 20th of June and are looking forward, with much pleasure, to our association

with you and Lazear in this interesting work. As far as I can see we have a year or two of work before us.

Trusting you will let me hear from you promptly, and with best wishes,

Sincerely yours,

(Signed)

WALTER REED

On the afternoon of June 25, 1900, the four officers met for the first time in their new capacity, on the veranda of the officers' quarters at Columbia Barracks Hospital. We were fully appreciative of the trust and aware of the responsibility placed upon us and with a feeling akin to reverence heard the instructions which Major Reed had brought from the surgeon general; they comprised the investigation also of malaria, leprosy and unclassified febrile conditions, and were given with such detail and precision as only a man of General Sternberg's experience and knowledge in such matters could have prepared. After deciding upon the first steps to be taken, it was unanimously agreed that whatever the result of our investigation should turn out to be, it was to be considered as the work of the board as a body, and never as the outcome of any individual effort; that each one of us was to work in harmony with a general plan, though at liberty to carry out his individual methods of research. We were to meet whenever necessary, Drs. Reed, Carroll and Lazear to remain at the Barracks Hospital and I to stay in charge of the laboratory in Havana, at the Military Hospital, where I also had a ward into which yellow-fever cases from the city were often admitted.

Work was begun at once. Fortunately for our purpose, an epidemic of yellow fever existed in the town of Quemados, in close proximity to the military reservation of Camp Columbia. Even before the arrival of Reed and Carroll, Lazear and I had been studying its spread, following the cases very closely; subsequently a few autopsies were made by me, Carroll making cultures from the various tissues and Lazear securing fragments for microscopical examination; a careful record was kept and the results noted; cases gradually became less in number as the epidemic slowly died out, about the middle of August.

In the meantime a rather severe outbreak of yellow fever had occurred in Santa Clara, a city in the interior of the island, having invaded the garrison and caused the death of several soldiers; as the origin of the infection was shrouded in mystery, and cases continued to appear among the troops even after they had moved out of the town, it was agreed that I should endeavor to trace the source of the epidemic and aid the medical authorities in establishing whatever preventive measures might seem proper. This service is here recorded because in the general discussion of the start and course of the epidemic with Dr. J. Hamilton Stone, the officer in charge of the military hospital, we incidentally spoke of the possible agency of insects in spreading the disease, pointing particularly in this direction the fact of the infection of a trooper who.

suffering from another complaint, occupied a bed in a ward across the yard from where a yellow fever case had developed two weeks before.

The infection of the city of Santa Clara had evidently taken place from Havana, distant only one night's journey by train. Captain Stone, a particularly able officer, had already instituted effective quarantine measures before my arrival, so that I only remained there a few days.

But as to the actual cause of the disease we were still entirely at sea; it helped us little to know that a man could be infected in Havana, take the train for a town in the interior and start an outbreak there in the course of time.

Upon rejoining my colleagues (July 2) we resumed our routine investigations; not only in Quemados, where the disease was being stamped out, but also in Havana, at "Las Animas" Hospital and at Military Hospital No. 1, where my laboratory (the division laboratory) was located. There was no scarcity of material and the two members who until then had never seen a case of yellow fever (Reed and Carroll) had ample opportunity, and took advantage of it, to become acquainted with the many details of its clinical picture which escape the ordinary practitioner, the knowledge and the appreciation of which, in their relative value, give the right to the title of "expert."

Since the later part of June, reports had been coming to headquarters of an extraordinary increase of sickness among the soldiers stationed at Pinar del Rio, the capital of the extreme western province, and very soon the great mortality from so-called "pernicious malarial fever" attracted the attention of the chief surgeon, Captain A. N. Stark, who, after consulting with Major Reed, ordered me to go there and investigate. A man had died, supposedly from malaria, just before my arrival on the afternoon of July 19. The autopsy which I performed at once showed me that yellow fever had been the cause of his death, and a search through the military hospital wards revealed the existence of several unrecognized cases being treated as malaria; a consultation held with the medical officer in charge showed me his absolute incapacity, as he was under the influence of opium most of the time (he committed suicide several months afterwards), and so I telegraphed the condition of things to headquarters; in answer I received the following:

CHIEF SURGEON'S OFFICE,
HDQRS. DEPT. HAVANA AND PINAR DEL RIO,
QUEMADOS, CUBA, July 20, 1900

SURGEON AGRAMONTE,
Pinar del Rio Barracks,
Pinar del Rio, Cuba

Report received last night. My thanks are due for your prompt action and confirmation of my suspicions.

STARK,
Chief Surgeon

Conditions in the hospital were such as to demand immediate action; the commander of the post refused to believe he had yellow fever among his 900 men and was loath to abandon his comfortable quarters for the tent life in the woods that I earnestly recommended. In answer to my telegram asking for official support, I received the following:

CHIEF SURGEON'S OFFICE,
HDQRS. DEPT. HAVANA AND PINAR DEL RIO,
QUEMADOS, CUBA, July 21, 1900

SURGEON AGRAMONTE,
Pinar del Rio Barracks,
Pinar del Rio, Cuba

Take charge of cases. Reed goes on morning train. Wire for anything wanted. Nurses will be sent. Instructions wired commanding officer. Other doctors should not attend cases. Establish strict quarantine at hospital. You will be relieved as soon as an immune can be sent to replace you. Report daily by wire.

STARK,
Chief Surgeon

When Major Reed came to Pinar del Rio (July 21) I had, the day before, established a separate yellow-fever hospital, under tents, attended by some of the men who had already passed an attack and were thus immune. The Major and I went over the ground very carefully, we studied the sick report for two months back, fruitlessly trying to place the blame upon the first case. I well remember how, as we stood in the men's sleeping quarters, surrounded by a hundred beds, from several of which fatal cases had been removed, we were struck by the fact that the later occupants had not developed the disease. In connection with this, and particularly interesting, was the case of a soldier prisoner who had been confined to the guard-house since June 6; he showed the first symptoms of yellow fever on the twelfth and died on the eighteenth; none of the other eight prisoners in the same cell caught the infection, though one of them continued to sleep in the same bunk previously occupied by his dead comrade. More than this; the three men who handled the clothing and washed the linen of those who had died during the last month were still in perfect health. Here we seemed to be in the presence of the same phenomenon remarked by Captain Stone in reference to his case at Santa Clara, and before that by several investigators of yellow-fever epidemics; the infection at a distance, the harmless condition of bedding and clothing of the sick; the possibility that some insect might be concerned in spreading the disease deeply impressed us and Major Reed mentions the circumstance in his later writings. This was really the first time that the mosquito transmission theory was seriously considered by members of the board, and it was decided that, although discredited by the repeated failure of its most ardent supporter, Dr. Carlos J. Finlay, of Havana, to demonstrate it, the matter should be taken up by the board and thoroughly sifted.

The removal of the troops out of Pinar del Rio was the means of at once checking the propagation of the disease.

On the first day of August the board met and after due deliberation determined to investigate mosquitoes in connection with the spread of yellow fever. As Dr. Lazear was the only one of us who had had any experience in mosquito work, Major Reed thought proper that he should take charge of this part of the investigation in the beginning, while we, Carroll and I, continued with the other work on hand, at the same time gradually becoming familiar with the manipulations necessary in dealing with the insects.

A visit was now made to Dr. Finlay, who, much elated at the news that the board was about to investigate his pet theory, the transmission of yellow fever from man to man by mosquitoes, very kindly explained to us many points regarding the life of the one kind he thought most guilty and ended by furnishing us with a number of eggs which, laid by a female mosquito nearly a month before, had remained unhatched on the inside of a half empty bowl of water in his library.

Much to our disappointment and regret, during the first week of August, Major Reed was recalled to Washington that he might, in collaboration with Drs. Vaughan and Shakespeare, complete the report upon "Typhoid Fever in the Army." Thus we were deprived of his able counsel during the first part of the mosquito research. Major Reed was detained longer than he expected and could not return to Cuba until early in October, several days after Lazear's death.

The mosquito eggs obtained from Dr. Finlay hatched out in due time; the insects sent to Washington for their exact classification were declared by Dr. L. O. Howard, entomologist to the Agricultural Department, to be *Culex fasciatus*. Later, they have been called *Stegomyia fasciatus* and now go under the name of *Stegomyia calopus* (*Aedes cal.*).

Lazear applied some of these mosquitoes to cases of yellow fever at "Las Animas" Hospital, keeping them in separate glass tubes properly labeled, and every thing connected with their bitings was carefully recorded; the original batch soon died and the work was carried on with subsequent generations from the same.

The lack of material at Quemados caused us to remove our field of action to Havana, where cases of yellow fever continued to appear. We met almost every day at "Las Animas" Hospital, where Lazear was trying to infect his mosquitoes, or now and then I performed autopsy upon a case, and Carroll secured sufficient cultures to last him for several days of bacteriological investigation.

Considering that, in case our surmise as to the insect's action should prove to be correct, it was dangerous to introduce infected mosquitoes amongst a population of 1,400 non-immunes at Camp Columbia, Dr. Lazear thought best to keep his presumably infected insects in my labo-

ratory at the Military Hospital No. 1, from where he carried them back and forth to the patients who were periodically bitten.

Incidentally, after the mosquitoes fed upon the yellow fever patients, they were applied, at intervals of two or three days, to whoever would consent to run the risk of contracting yellow fever in this way; needless to say, current opinion was against this probability and as time passed and numerous individuals who had been bitten by insects which had previously fed upon yellow fever blood remained unaffected, I must confess that even the members of the board, who were rather sanguine in their expectations, became somewhat discouraged and their faith in success very much shaken.

No secret was made of our attempts to infect mosquitoes; in fact many local physicians became intensely interested, and Lazear and his tubes were the subject of much comment on the part of the Havana doctors, who nearly twenty years before had watched and laughed at Dr. Finlay, then bent apparently upon the same quest in which we were now engaged. Dr. Finlay himself was somewhat chagrined when he learned of our failure to infect any one with mosquitoes, but, like a true believer, was inclined to attribute this negative result more to some defect in our technique than to any flaw in his favorite theory.

Although the board had thought proper to run the same risks, if any, as those who willingly and knowingly subjected themselves to the bites of the supposedly infected insects, opportunity did not offer itself readily, since Major Reed was away in Washington and Carroll, at Camp Columbia, engrossed in his bacteriological investigations came to Havana only when an autopsy was on hand or a particularly interesting case came up for study. I was considered an immune, a fact that I would not like to have tested, for though born in the island of Cuba, I had practically lived all my life away from a yellow-fever zone; it was therefore presumed that I ran no risk in allowing mosquitoes to bite me, as I frequently did, just to feed them blood, whether they had previously sucked from yellow-fever cases or not. And so, time passed and several Americans and Spaniards had subjected themselves in a sporting mood to be bitten by the infected (?) mosquitoes without causing any untoward results, when Lazear applied to himself (August 16, 1900) a mosquito which ten days before had fed upon a mild case of yellow fever in the fifth day of his disease; the fact that no infection resulted, for Lazear continued in excellent health for a space of time far beyond the usual period of incubation, served to discredit the mosquito theory in the opinion of the investigators to a degree almost beyond redemption, and the most enthusiastic, Dr. Lazear himself, was almost ready to "throw up the sponge."

I had as laboratory attendant a young American, a private belonging to the Hospital Corps of the Army, who more than once had bared his

arm to allow a weak mosquito a fair meal with which to regain its apparently waning strength; Loud, for that was his name, derided the idea that such a little beast could do so much harm as we seemed ready to accuse it of, although he was familiar with the destruction caused by bacteria, but then, he used to say, "bacterias work in armies of more than a million bugs at the same time and no one would be d—— fool enough to let more than one or two gnats sting him at once."

This state of things, the gradual loss of faith in the danger which mosquitoes seemed to possess, led Dr. Lazear to relax a little and become less scrupulous in his care of the insects, and often, after applying them to patients, if pressed for time, he would take them away with him to his laboratory at Columbia Barracks, where, the season being then quite warm, they could be kept as comfortably as at the Military Hospital laboratory. Thus it happened that on the twenty-seventh of August he had spent the whole morning at "Las Animas" Hospital getting his mosquitoes to take yellow-fever blood: the procedure was very simple; each insect was contained in a glass tube covered by a wad of cotton, the same as is done with bacterial cultures. As the mouth of the tube is turned downwards, the insect usually flies towards the bottom of the tube (upwards), then the latter is uncovered rapidly and the open mouth placed upon the forearm or the abdomen of the patient; after a few moments the mosquito drops upon the skin and if hungry will immediately start operations; when full, by gently shaking the tube, the insect is made to fly upwards again and the cotton plug replaced without difficulty. It so happened that this rather tedious work, on the day above mentioned, lasted until nearly the noon hour, so that Lazear, instead of leaving the tubes at the Military Hospital, took them all with him to Camp Columbia: among them was one insect that for some reason or other had failed to take blood when offered to it at "Las Animas" Hospital.

This mosquito had been hatched in the laboratory and in due time fed upon yellow-fever blood from a severe case on August 15, that is, twelve days before, the patient then being in the second day of his illness; also at three other times, six days, four days and two days before. Of course, at the time, no particular attention had been drawn to this insect, except that it refused to suck blood when tempted that morning.

After luncheon that day, as Carroll and Lazear were in the laboratory attending to their respective work, the conversation turning upon the mosquitoes and their apparent harmlessness, Lazear remarked how one of them had failed to take blood, at which Carroll thought that he might try to feed it, as otherwise it was liable to die before next day (the insect seemed weak and tired); the tube was carefully held first by Lazear and then by Carroll himself, for a considerable length of time, upon his forearm, before the mosquito decided to introduce its proboscis.

This insect was again fed from a yellow fever case at "Las Animas"

Hospital on the twenty-ninth, two days later, Dr. Carroll being present, though not feeling very well, as it was afterwards ascertained.

We three left the yellow-fever hospital together that afternoon; I got down from the doherty-wagon where the road forks, going on to the Military Hospital, while Carroll and Lazear continued on their way to Camp Columbia. On the following day, Lazear telephoned to me in the evening, to say that Carroll was down with a chill after a sea bath taken at the beach, a mile and a half from Camp, and that they suspected he had malaria; we therefore made an appointment to examine his blood together the following morning.

When I reached Camp Columbia I found that Carroll had been examining his own blood early that morning, not finding any malarial parasites; he told me he thought he had "caught cold" at the beach: his suffused face, blood-shot eyes and general appearance, in spite of his efforts at gaiety and unconcern, shocked me beyond words. The possibility of his having yellow fever did not occur to him just then; when it did, two days later, he declared he must have caught it at my autopsy room in the Military Hospital, or at "Las Animas" Hospital, where he had been two days before taking sick. Although we insisted that he should go to bed in his quarters, we could only get him to rest upon a lounge, until the afternoon, when he felt too sick and had to take to his bed.

Lazear and I were almost panic-stricken when we realized that Carroll had yellow fever. We searched for all possibilities that might throw the blame for his infection upon any other source than the mosquito which bit him four days before; Lazear, poor fellow, in his desire to exculpate himself, as he related to me the details of Carroll's mosquito experiment, repeatedly mentioned the fact that he himself had been bitten two weeks before without any effect therefrom and finally, what seemed to relieve his mind to some extent, was the thought that Carroll offered himself to feed the mosquito and that he held the tube upon his own arm until the work was consummated.

I have mentioned before that, as Lazear and I, vaguely hoping to find malarial parasites in Carroll's blood, sat looking into our microscopes that morning, the idea that the mosquito was what brought him down gradually took hold of our minds, but as our colleague had been exposed to infection in other ways, by visiting the yellow fever hospital "Las Animas," as well as the infected city of Havana, it was necessary to subject that same mosquito to another test and hence the inoculation of Private Dean, which is described in the opening chapter of this history.

TERMINATION OF THE FIRST SERIES OF MOSQUITO EXPERIMENTS. DEATH OF LAZEAR.

The month of September, 1900, was fraught with worry and anxiety: what with Carroll's and Private Dean's attacks of yellow fever

and Major Reed's inability to return, Lazear and I were well-nigh on the verge of distraction. Private Dean was not married, but Carroll's wife and children, a thousand miles away, awaited in the greatest anguish the daily cablegram which told them the condition of the husband and father, who was fighting for life, sometimes the victim of the wildest delirium caused by consuming fever, at others almost about to collapse, until one day, the worst of the disease being over, the wires must have thrilled at our announcement, "Carroll out of danger."

Fortunately both he and Dean made an uninterrupted recovery, but we were still to undergo the severest trial, a sorrow compared to which the fearful days of Carroll's sickness lose all importance and dwindle almost into insignificance.

On the morning of the eighteenth my friend and classmate Lazear, whom in spite of our short intercourse I had learned to respect and in every way appreciate most highly, complained that he was feeling "out of sorts." He remained all day about the officers' quarters and that night suffered a moderate chill. I saw him the next day with all the signs of a severe attack of yellow fever.

Carroll was already walking about, though enfeebled by his late sickness, and we both plied Lazear with questions as to the origin of his trouble; I believe we affectionately chided him for not having taken better care of himself. Lazear assured us that he had not experimented upon himself, that is, that he had not been bitten by any of the purposely infected mosquitoes.

After the case of Dean so plainly demonstrated the certainty of mosquito infection, we had agreed not to tempt fate by trying any more upon ourselves, and even I determined that no mosquito should bite me if I could prevent it, since the subject of my immunity was one that could not be sustained on scientific grounds; at the same time, we felt that we had been called upon to accomplish such work as did not justify our taking risks which then seemed really unnecessary. This we impressed upon Major Reed when he joined us in October and for this reason he was never bitten by infected mosquitoes.

Lazear told us, however, that while at "Las Animas" Hospital the previous Thursday (five days before), as he was holding a test-tube with a mosquito upon a man's abdomen, some other insect which was flying about the room rested upon his hand; at first, he said, he was tempted to frighten it away, but, as it had settled before he had time to notice it, he decided to let it fill and then capture it; besides, he did not want to move in fear of disturbing the insect contained in his tube, which was feeding voraciously. Before Lazear could prevent it, the mosquito that bit him on the hand had flown away. He told us in his lucid moments, that, although Carroll's and Dean's cases had convinced him of the mosquito's rôle in transmitting yellow fever, the fact that no in-

fection had resulted from his own inoculation the month before had led him to believe himself, to a certain extent, immune.

How can I describe the agony of suspense which racked our souls during those six days? It seemed to us as though a life was being offered in sacrifice for the thousands which it was to contribute in saving. Across the span of thirteen years the memory of the last moments comes to me most vividly and thrilling, when the light of reason left his brain and shut out of his mind the torturing thought of the loving wife and daughter far away, and of the unborn child who was to find itself fatherless on coming to the world.

Tuesday, the twenty-fifth of September saw the end of a life full of promise; one more name, that of Jesse W. Lazear, was graven upon the portals of immortality. And we may feel justly proud for having had it, in any way, associated with our own.

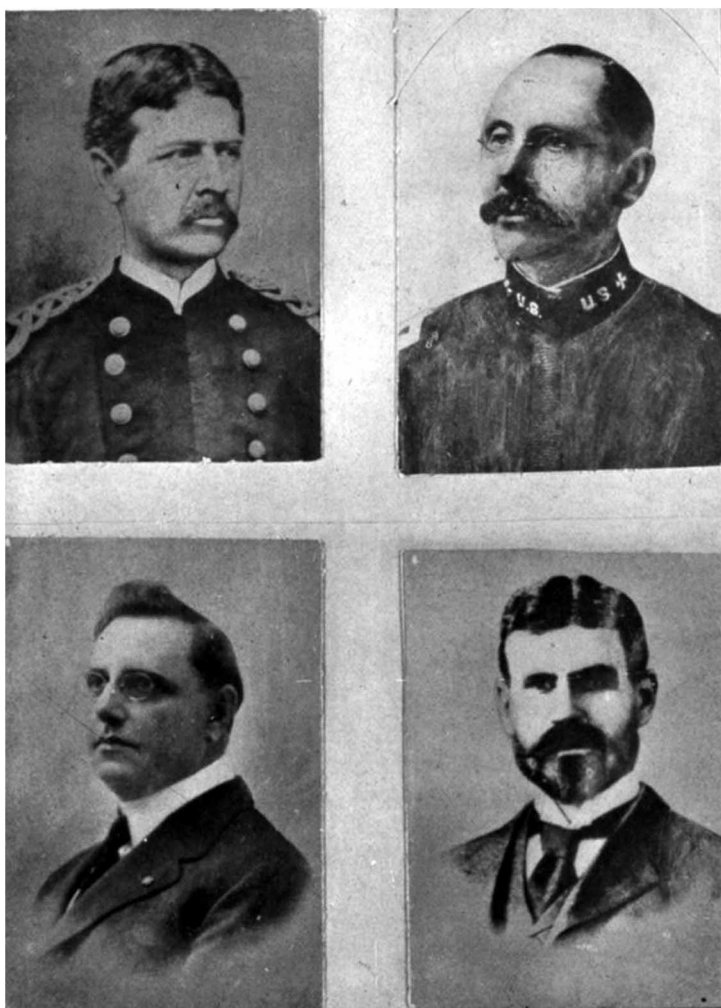
The state of mind in which this calamity left us may better be imagined than described. The arrival of Major Reed several days after in a great measure came to relieve the tensivity of our nerves and render us a degree of moral support of which we were sorely in need.

Lazear's death naturally served to dampen our fruition at the success of the mosquito experiments, but, this notwithstanding, when the facts were known we were the subjects of much congratulation and the question whether the theory had been definitely demonstrated or not was the theme of conversation everywhere, about Havana and Camp Columbia particularly. We fully realized that three cases, two experimental and one accidental, were not sufficient proof, and that the medical world was sure to look with doubt upon any opinion based on such meager evidence; besides, in the case of Carroll, we had been unable to exclude the possibility of other means of infection, so that we really had but one case, Dean's, that we could present as clearly demonstrative and beyond question. In spite of this, we thought that the results warranted their presentation in the shape of a "Preliminary Note," and after all the data were carefully collected from Lazear's records and those at the Military Hospital, a short paper was prepared which the Major had the privilege to read at the meeting of the American Public Health Association, held on October 24, in the city of Indianapolis.

For this purpose Major Reed went to the States two weeks after his return to Cuba, and Carroll also took a short leave of absence so as to fully recuperate, in preparation for the second series of inoculations which we had arranged to undertake, after the Indianapolis meeting.

These inoculations, according to our program, were to be made upon volunteers who should consent to suffer a period of previous quarantine at some place to be selected in due time, away from any possibility of yellow fever.

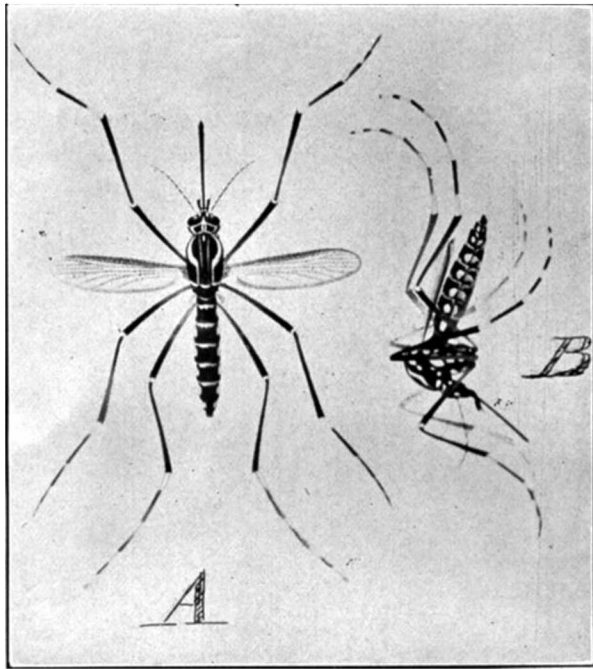
It so happened then that I was left the only member of the board in Cuba and, under instructions from Major Reed, I began to breed mos-



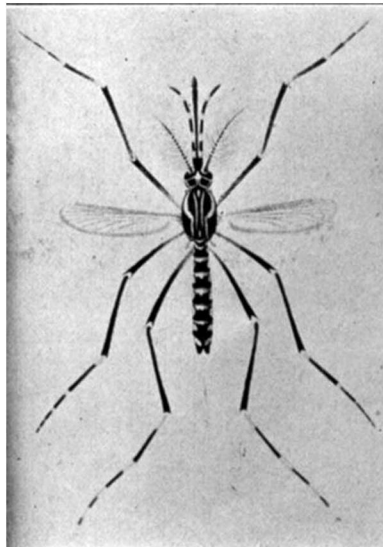
THE UNITED STATES ARMY YELLOW-FEVER BOARD.

MAJOR WALTER REED.
DR. ARISTIDES AGRAMONTE.

DR. JAMES CARROLL.
DR. JESSE W. LAZEAR.



FEMALE YELLOW-FEVER MOSQUITO—(*Stegomyia Calopus*). (A) The insect spread out to show the "lyre" marking on the back. (B) Position of the insect when ready to introduce its sting.



MALE YELLOW-FEVER MOSQUITO (*Stegomyia Calopus*). Showing the feathery antennæ peculiar to the sex in most mosquitoes.

quitoes and infect them, as Lazear used to do, wherever cases occurred, keeping them at my laboratory in the Military Hospital No. 1. Major Reed had also asked me to look about for a proper location wherein to continue the work upon his return.

ORIGIN AND DEVELOPMENT OF THE MOSQUITO THEORY

The possible agency of insects in the propagation of yellow fever was thought of by more than one observer, from a very early period in the history of this disease. For instance, Rush, of Philadelphia, in 1797, noticed the excessive abundance of mosquitoes during that awful epidemic. Subsequently, several others spoke of the coincidence of gnats or mosquitoes and yellow fever, but without ascribing any direct relation to the one regarding the other. Of course, man-to-man infection through the sole intervention of an insect was a thing entirely inconceivable and therefore unthought of until very recently, and in truth the discovery, as far as yellow fever is concerned, was the result of a slow process of evolution of the fundamental fact, taken in connection with similar findings, in other diseases.

The earliest direct reference is found in the writings of Dr. Nott, of Mobile, Ala., who in 1848 suggested that the dissemination of the yellow-fever poison was evidently by means of some insect "that remained very close to the ground." But the first who positively pointed to the mosquito as the spreader of yellow fever, who showed that absence of mosquitoes precluded the existence of the disease and who prescribed the ready means to stamp it out, by fumigation and by preventing the bites of the insects, was Dr. Louis D. Beauperthuy, a French physician, then located in Venezuela. The writer has an original copy of his paper, published in 1853, where he fastens the guilt upon the domestic mosquitoes, believing, in accord with the prevailing teachings of medical science, that the mosquitoes infected themselves by contact or feeding upon the organic matter found in the stagnant waters where they are hatched, afterwards inoculating the victims by their sting. He recognized the fact that yellow fever is not contagious and therefore could not think of the possibility of man-to-man infection, as we know it to-day. The keenest observer was this man Beauperthuy, and, even at that benighted time in the history of tropical medicine, made most interesting studies of the blood and tissues, employing the microscope and the chemical reactions in his research. No one believed him, and a commission appointed to report upon his views said that they were inadmissible and all but declared him insane.

This field of investigation remained dormant for a comparatively long period of time. Meanwhile another medical writer, Dr. Greenville Dowell, mentions in 1876, that "if we compare the effect of heat and cold on gnats and mosquitoes with yellow fever, it will be difficult to believe it is of the same nature, as it is controlled by the same natural



METHOD OF FEEDING BLOOD TO MOSQUITOES; also used later for infecting them and for applying the insects to those who were inoculated.

laws." Soon after this, in 1879, the first conclusive proof of the direct transmission of a disease from man-to-man was presented by the father of tropical medicine, Sir Patrick Manson, with regard to filaria, a blood infection that often causes the repulsive condition known as elephantiasis and which the mosquito takes from man and after a short time gives over to another subject. This discovery attracted world-wide attention and many looked again towards the innumerable species of biting insects that dwell in the Tropic Zone, as possible carriers of the obscure diseases which also prevail in those regions.

In 1881, Dr. Carlos Finlay, of Havana, in an exhaustive paper read before the Royal Academy of Sciences, gave as his opinion that yellow fever was spread by the bites of mosquitoes "directly contaminated by stinging a yellow fever patient (or perhaps by contact with or feeding from his discharge)." This latter view he held as late as 1900, which, although correct in the main fact of the transmission of the germ from a patient to a susceptible person by the mosquito, the *modus operandi*, as he conceived it, was entirely erroneous.

Dr. Finlay, unfortunately, was unable to produce experimentally

a single case of fever that could withstand the mildest criticism, so that at the time when the Army Board came to investigate the causes of yellow fever in Cuba, his theory, though practically the correct one, had been so much discredited, in a great measure by his own failures, that the best-known experts considered it as an ingenious, but wholly fanciful, one and many thought it a fit subject for humorous and sarcastic *repartee*. Finlay also believed, erroneously, that repeated bites of contaminated insects might protect against yellow fever and that the mosquitoes were capable of transmitting the germ to the next generation.

The wonderful discoveries of Theobald Smith, as to the agency of ticks in spreading Texas fever of cattle, and those of Ross and the Italian investigators who showed conclusively that malaria was transmitted by a species of mosquito, brought the knowledge of these various diseases to the point where the Army Board took up the investigation of yellow fever.

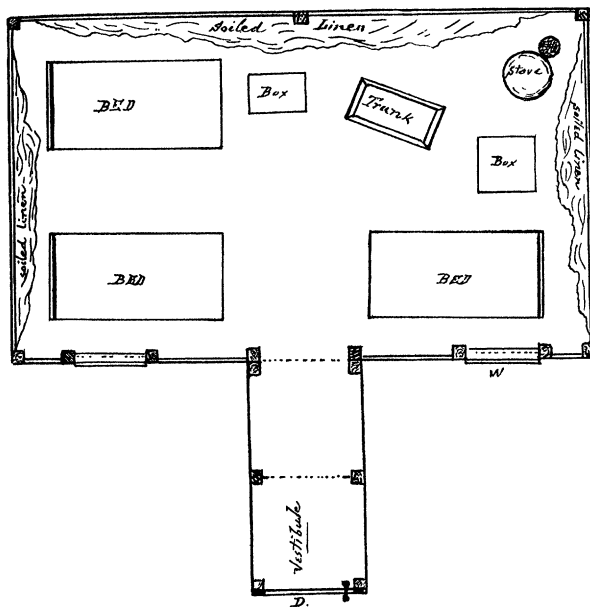
SECOND AND FINAL SERIES OF MOSQUITO EXPERIMENTS

Major Reed came back to Havana in the early part of November, Carroll following a week after.

During their absence, I had been applying mosquitoes to yellow-fever patients at "Las Animas" Hospital, keeping them in my laboratory, as it was done at the beginning of the investigation; the season being more advanced, now and then a cold "norther" would blow and my insects suffered very much thereby, so that I had the greatest trouble in preventing their untimely death: to this may be added the difficulty met in feeding them blood, for now that I knew their sting was dangerous, unto death perhaps, I could not allow any indiscriminate biting, but had to select for the purpose individuals who had suffered an attack of the disease and were therefore immune.

The necessity for an experimental camp became more imperative as time passed, not only where proper quarantine and isolation could be established, but also where the insects intended for the inoculations might receive better care. This entailed considerable expense.

Fortunately for us, the military governor of the island at that time, Brigadier General Leonard Wood, was a man who had received a thorough medical training; broad and clear-minded, he fully appreciated the importance of what might be the outcome of our researches. We found in him the moral support which we so much needed and, further, he promptly placed at the disposal of the board sufficient funds with which to carry on the experiments to the end. I firmly believe that had other been the circumstances, had a more military and less scientific man been at the head of the government, the investigation would have terminated there and then, and many years would have passed, with



PLAN OF THE "INFECTED CLOTHING BUILDING" AT CAMP LAZEAR. Men who were susceptible to the disease slept many nights in this soiled linen room, without contracting yellow fever.

hundreds of lives uselessly sacrificed, before we could have attained our present remarkable sanitary triumphs.

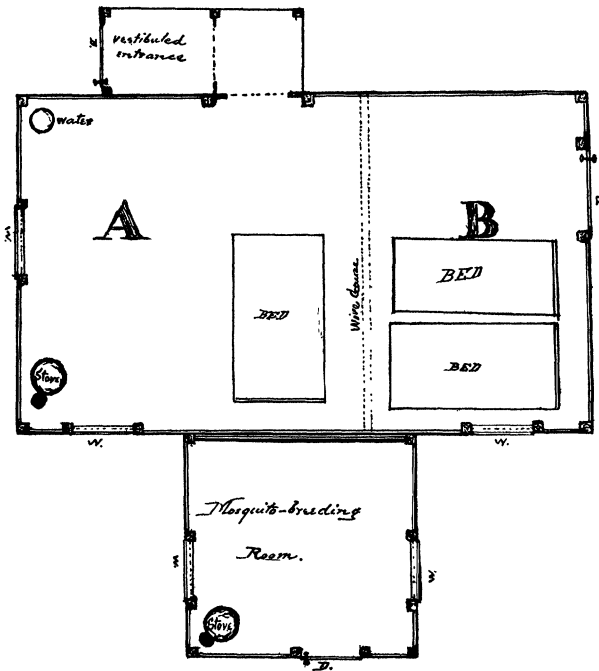
We immediately set about choosing a location for our camp. I had already looked over the ground, preferring the proximity of Camp Columbia, from where supplies could be easily obtained and because the Military Hospital there could be used for treating the cases that we intended to produce; I was therefore favorably impressed with the seclusion offered by a spot situated a short distance from the main road, in a farm, named San José, belonging to my friend Dr. Ignacio Rojas, of Havana. Major Reed decided upon this place after looking at many others in the neighborhood, so that on the twentieth of November we inaugurated our camp, which we named Camp Lazear, in honor to the memory of our dead colleague, consisting then of seven army tents, guarded by a military garrison, composed of men who had been carefully selected by virtue of their previous good record and their interest in the work to be undertaken.

Feeling that we had proved, to ourselves at least, the agency of the mosquito in yellow fever, it became our duty to disprove the theory, until then held as a certainty by many authorities, to the effect that the soiled bedding and clothing, the secretions and excreta of patients, were infectious and in some way carried the germ of the disease. We therefore designed a small wooden building, to be erected a short distance from the tents, with a capacity of 2,800 cubic feet. The walls and

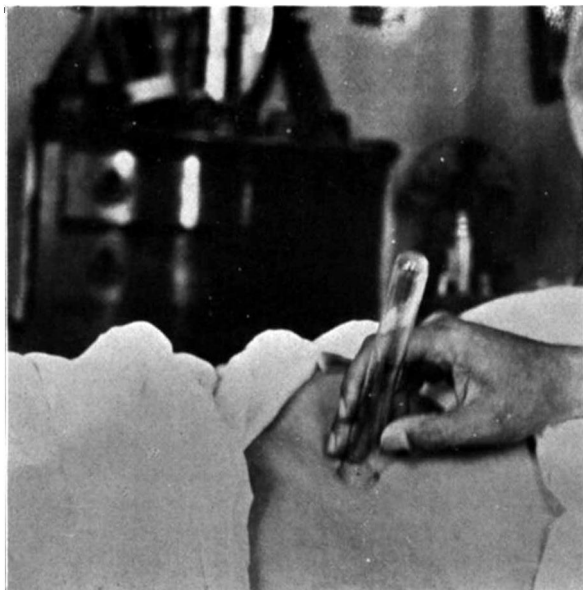
ceiling were absolutely tight, the windows and vestibuled door screened and all precautions taken to prevent the entrance of insects.

Into this, called the "infected clothing building," three beds and a stove, to maintain a high tropical temperature, were introduced; also mattresses and pillows, underwear, pajamas, towels, sheets, blankets, etc., soiled with blood and discharges from yellow fever cases: these articles were put on the beds, hung about the room and packed in a trunk and two boxes placed there for the purpose.

The building was finished and equipped on November 30. That Friday evening, Dr. Robert P. Cook, U. S. Army, with two other American volunteers, entered it and prepared to pass the night: they had instructions to unpack the boxes and trunk, to handle and shake the clothing and in every way to attempt to disseminate the yellow fever poison, in case it was contained in the various pieces. We watched the proceedings from the outside, through one of the windows. The foul conditions which developed upon opening the trunk were of such a character that the three men were seen to suddenly rush out of the building into the fresh air; one of them was so upset that his stomach rebelled; yet, after a few minutes, with a courage and determination worthy only of such a cause, they went back into the building and passed a more or



PLAN OF THE "MOSQUITO BUILDING" AT CAMP LAZEAR. The man who for a short time occupied the bed in room marked "A" became infected by the bites of mosquitoes previously introduced, while those, equally susceptible, who occupied beds in section marked "B" remained in good health. Only a wire-screen partition separated the two compartments.



METHOD OF INFECTING MOSQUITOES, ORIGINALLY USED BY DR. LAZEAR. The tube containing the mosquito is applied upon the abdomen of the patient.

less sleepless night, in the midst of indescribable filth and overwhelming stench.

For twenty consecutive nights these men went through the same performance; during the day they remained together, occupying a tent near their sleeping quarters. Dr. Cook, by voluntarily undergoing such a test, without remuneration whatsoever, proved his faith in the mosquito theory; his demonstration of the harmless character of so-called infected clothing, in yellow fever, has been of the greatest importance. The other six men (two of them with Dr. Cook) who were subjected to this test, received each a donation of one hundred dollars for his services.

Many days even before the establishment of the experimental camp, the board had heard that several men who knew of our work were willing to submit to the inoculations and thus aid in clearing up the mystery of yellow fever. Two of these require special mention, John R. Kissinger, a private in the Hospital Corps of the Army, was the first to offer himself most altruistically, for, as he expressed it, his offer was made without any desire for pecuniary or other consideration and solely "in the interest of humanity and the cause of science," the other, J. J. Moran, a civilian employee, also stipulated as a condition that he was to receive no pay for his services. Both these men, in due time, suffered from yellow fever and until very recently had never obtained any reward for the great risk which they ran so voluntarily and praiseworthily.

Kissinger, who after several years' service in the army became disabled, is receiving a pension from the government; Moran, I hope, is still well and in the employ of the Isthmian Canal Commission, justly enjoying the friendship and confidence of his superior officers. The names of Kissinger and Moran should figure upon the roll of honor of the U. S. Army.

On the day the camp was definitely organized, Kissinger, who had not gone outside the military reservation for more than a month, moved into Camp Lazear and received his first bite from a mosquito which evidently was not "loaded" for, again on November 23, he was stung by the same insect without result. On December 5, five mosquitoes were applied, which brought about a moderate infection in three days. Moran was also bitten by mosquitoes which were supposed to be infected on November 26 and 29, both times unsuccessfully. As will be seen, he was infected later on.

By this time we had decided, the weather having cooled considerably, that it was better to keep the mosquitoes at a higher temperature and nearer to the men who were to be inoculated; therefore it was planned to put up another small wooden structure, which was to be known as the "Mosquito Building" in which an artificial temperature could be maintained; at my suggestion, the building was so designed that it might serve to infect individuals; by liberating infected mosquitoes on the inside and exposing some person to their stings, we could try to reproduce the infection as we felt it occurred in nature. Another reason for the mosquito house was the need to obviate the transportation of the insects from the Military Hospital, where I kept them, to our camp,



MOSQUITO CAGE (GLASS JAR WITH NETTING) USED FOR BREEDING INSECTS.

which could not be easily done without subjecting them to severe injury.

Upon one occasion I was taking four infected mosquitoes in the pocket inside my blouse from the laboratory in Havana to the experimental camp, accompanied by my attendant Private Loud; the horse which pulled my buggy, a rather spirited animal, becoming frightened at a steam roller, as we went around the corner of Colon Cemetery, started to race down the hill towards the Almendares River: Loud was thrown out by the first cavortings of the horse, who stood on its hind legs and jumped several times before dashing away, while I held tightly to the tubes in my pocket, as the buggy upset and left me stranded upon a sand pile in the middle of the road; the mosquitoes were quite safe, however, and upon my arrival at Camp Lazear I turned them over to Carroll for his subsequent care.

Another difficulty afterwards encountered was the scarcity of material susceptible to infection, for, although several men had expressed a willingness to be inoculated, when the time came, they all preferred the "infected clothing" experiment to the stings of our mosquitoes. We then thought best to secure lately landed Spaniards, to whom the probable outcome of the test might be explained and their consent obtained for a monetary consideration. Our method was as follows; as soon as a load of immigrants arrived, I would go to Tiscornia, the Immigration Station across the Bay of Havana, and hire eight or ten men, as day laborers, to work in our camp. Once brought in, they were bountifully fed, housed under tents, slept under mosquito-bars and their only work was to pick up loose stones from the grounds, during eight hours of the day, with plenty of rest between. In the meantime, as the days of observation passed, I carefully questioned them as to their antecedents, family history and the diseases which they might have suffered; those who had lived in Cuba or any other tropical country before were discarded at once and also those who were under age or had a family dependent upon them. When the selection was finally made, the matter of the experiment was put to them. Naturally, they all felt more or less that they were running the risk of getting yellow fever when they came to Cuba and so were not at all averse to allow themselves to be bitten by mosquitoes: they were paid one hundred dollars for this, and another equal sum if, as a result of the biting experiment, they developed yellow fever. Needless to say, no reference was made to any possible funeral expenses. A written consent was obtained from each one, so that our moral responsibility was to a certain extent lessened. Of course, only the healthiest specimens were experimented upon.

It so happened that some reporter discovered what we were about, or perhaps some invidious person misrepresented the facts; at any rate, on the twenty-first of November a Spanish newspaper appeared with flaring headlines denouncing the American doctors who were taking ad-

vantage of the poor immigrants and experimenting with them by injecting all sorts of poisons! It called upon the Spanish consul to look after his subjects. In view of this we felt that if such campaign continued, in a short time it would either make it impossible to secure subjects or cause diplomatic pressure to be exerted against the continuance of our experiments. It was thought best to "beard the lion in his den" so the three of us called upon the consul the following day. He was surprised to hear one of us address him in his own language, having taken us all for Americans on first sight, and when I explained to him our method of procedure and showed him the signed contracts with the men, being an intelligent man himself, he had no objections to offer and told us to go ahead and not bother about any howl the papers might make.

The first three cases (two of them Spaniards) which we produced came down with yellow fever within a very short period, from December 8 to 13; it will therefore not surprise the reader to know that when the fourth case developed on December 15, and was carried out of the camp to the hospital, it caused a veritable panic among the remaining Spaniards, who, renouncing the five hundred pesetas that each had in view, as Major Reed very aptly put it, "lost all interest in the progress of science and incontinentally severed their connection with Camp Lazear."

But there was a rich source to draw from, and the unexpected stampede only retarded our work for a short time. Our artificial epidemic of yellow fever was temporarily suspended while a new batch of susceptible material was brought in, observed and selected. The next case for that reason was not produced upon a Spaniard until December 30.

In the face of the negative experiments with supposedly contaminated articles, it rested with us to show how a house became infected and for this purpose the main part of the "mosquito building" was utilized.

This chamber was divided into two compartments by a double wire-screen partition, which effectually prevented mosquitoes on one side from passing to the other; of course there were no mosquitoes there to begin with, as the section of the building used for breeding and keeping them was entirely separated from the other, and there could be no communication between them.

On the morning of December 21, a jar containing fifteen hungry mosquitoes, that had previously stung cases of yellow fever, was introduced and uncovered in the larger compartment, where a bed, with all linen perfectly sterilized, was ready for occupancy. A few minutes after, Mr. Moran, dressed as though about to retire for the night, entered the room and threw himself upon the bed for half an hour; during this time two other men and Major Reed remained in the other compart-

ment, separated from Moran only by the wire-screen partition. Seven mosquitoes were soon at work upon the young man's arms and face; he then came out, but returned in the afternoon, when five other insects bit him in less than twenty minutes. The next day, at the same hour of the afternoon, Moran entered the "mosquito building" for the third time and remained on the bed for fifteen minutes, allowing three mosquitoes to bite his hands. The room was then securely locked, but the two Americans continued to sleep in the other compartment for nearly three weeks, without experiencing any ill effects.

Promptly on Christmas morning Moran, who had not been exposed to infection except for his entrance into the "mosquito building" as described, came down with a well-marked attack of yellow fever.

The temperature in this room, where these mosquitoes had been released, was kept rather high and a vessel with water was provided, where they might lay their eggs if so inclined, but notwithstanding all these precautions, it was subsequently found that the insects had been attacked by ants, so that by the end of the month only one of the fifteen mosquitoes remained alive.

It is hardly necessary to detail here how seven other men were subjected to the sting of our infected mosquitoes, of which number five developed the disease, but it may be interesting to note that two of these men had been previously exposed in the "infected clothing building" without their becoming infected, showing that they were susceptible to yellow fever after all.

The evidence so far seemed to show that the mosquito could only be infected by sucking blood of a yellow-fever patient during the first three days of the disease; to prove that the parasite was present in the circulating blood at that time we therefore injected some of this fluid taken from a different case each time, under the skin of five men: four of these suffered an attack of yellow fever as the result of the injection. The other one, a Spaniard, could not be infected either by the injection of blood or the application of mosquitoes which were known to be infected, showing that he had a natural immunity or, more likely, that he had had yellow fever at some previous time.

While selecting the Spaniards, it was often ascertained that they had been in Cuba before, as soldiers in the Spanish army usually, and the natural conclusion was that they had undergone infection; it was very seldom that any escaped during the Spanish control of the island.

Thus terminated our experiments with mosquitoes which, though necessarily performed on human beings, fortunately *did not cause a single death*; on the other hand, they served to revolutionize all standard methods of sanitation with regard to yellow fever. They showed the uselessness of disinfection of clothing and how easily an epidemic can be stamped out in a community by simply protecting the sick from the sting of the mosquitoes and by the extensive and wholesale destruction

of these insects which, added to the suppression of their breeding places, if thoroughly carried out, are the only measures necessary to forever rid a country of this scourge.

Besides keeping a sharp lookout against the importation of yellow fever cases, these are the simple rules that have kept the Panama Canal free and prevented the slaughter of hundreds of foreigners, so generally expected every year, in former times.

Since we made our demonstration in 1901, our work has been corroborated by various commissions appointed for the purpose, in Mexico, Brazil and Cuba, composed variously of Americans, French, English, Cuban, Brazilian and German investigators. Nothing has been added to our original findings; nothing has been contradicted of what we have reported, and to-day, after nearly thirteen years, the truths that we uncovered stand incontrovertible; besides, they have been the means of driving out yellow fever from Cuba, the United States (Laredo, Texas, 1903 and New Orleans, La., 1905), British Honduras and several cities of Brazil.

Of the Army Board only I remain. Lazear, as reported, died during the early part of our investigations; Reed left us in 1902 and Carroll only five years later. The reader may wonder of what benefit was it to us, this painstaking and remarkable accomplishment which has been such a blessing to humanity! See what the late Surgeon General of the U. S. Army had to say in his report (Senate Document No. 520, Sixty-first Congress, second session):

1. Major Walter Reed, surgeon, United States Army, died in Washington, D. C., from appendicitis, November 23, 1902, aged 51. His widow, Emilie Lawrence Reed, is receiving a pension of \$125 a month.

2. Maj. James Carroll was promoted from first lieutenant to major by special act of Congress, March 9, 1907. He died in Washington, D. C., of myocarditis, September 16, 1907. His widow, Jennie H. Carroll, since his death, has received an annuity of \$125 a month, appropriated from year to year in the Army appropriation bill.

3. Dr. Jesse W. Lazear, contract surgeon, United States Army, died at Camp Columbia, Cuba, of yellow fever, September 25, 1900. His widow, Mabel M. Lazear, since his death, has received an annuity of \$125 a month appropriated from year to year in the Army appropriation bill.

4. Dr. Aristides Agramonte is the only living member of the board. He is professor of bacteriology and experimental pathology in the University of Habana and has never received, either directly or indirectly, any material reward for his share in the work of the board.

It is not for me to make any comments: the above paragraphs have all the force of a plain, truthful statement of facts. Perhaps it is thought that enough reward is to be found in the contemplation of so much good derived from one's own efforts and the feeling it may produce of innermost satisfaction and in forming the belief that one had not lived in vain. In a very great measure, I know, the thought is true.